Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/US05/004675

International filing date: 11 February 2005 (11.02.2005)

Document type: Certified copy of priority document

Document details: Country/Office: US
Number: 60/543,768
Filing date: 11 February 2004 (11.02.2004)

Date of receipt at the International Bureau: 22 July 2005 (22.07.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

1344127

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

July 12, 2005

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE.

APPLICATION NUMBER: ***60/543,768***
FILING DATE: ***February 11, 2004***
RELATED PCT APPLICATION NUMBER: ***PCT/US05/04675***

UNITED STATES PATENT AND TRADEMARK OFFICE
DEPARTMENT OF COMMERCE

Certified by

Jon W. Dudas

Under Secretary of Commerce
for Intellectual Property
and Director of the United States
Patent and Trademark Office

Express Mail Number: EV 328704246 US
Date of Deposit: February 11, 2004 | **Attorney Docket No. 25960-013**

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR § 1.53(c)

INVENTORS / APPLICANTS	
Elan Scheinman	3884 Autumn Drive, Redwood City, CA 94061
Michael Ellenbogen	2 Plainview Road, Wayland, MA 01778
Richard Robehr Bijjani	15 Lynwood Lane, Westford, MA 01886

TITLE

CHECKPOINT CT SCANNER SYSTEM

CORRESPONDENCE ADDRESS

Attorney Name: Firm Name and Address:	Brett N. Dorny, Esquire MINTZ, LEVIN, COHN, FERRIS, GLOVSKY AND POPEO, P.C. One Financial Center Boston, MA 02111
Telephone:	(617) 542-6000
Fax:	(617) 542-2241

ENCLOSED APPLICATION PARTS

- ☒ **Specification** — Number of Pages: 9
- ☐ **Sequence Listing** — Number of Pages:
- ☒ **Drawings** (X) Informal — Number of Sheets: 1
- ☐ **Other documents** (specify):

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government:

- ☒ No.
- ☐ Yes, the name of the U.S. Government agency and the Government contract number are:

METHOD OF PAYMENT

- ☐ A check in the amount of **$80.00** is enclosed to cover the filing fees of the Provisional application.
- ☐ The Commissioner is hereby authorized to charge is enclosed to cover the filing fees of the Provisional application to Deposit Account No. 50-0311, Reference No. 25960.013
- ☒ The Commissioner is hereby authorized to charge additional fees or credit any overpayment to Deposit Account No. 50-0311, Reference No: 25960.013

Respectfully submitted,

Date: February 11, 2004

Brett N. Dorny, Registration No. 35,860
MINTZ, LEVIN, COHN, FERRIS, GLOVSKY AND POPEO, P.C.
One Financial Center
Boston, MA 02111
Telephone: (617) 542-6000

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT.
SEND TO: *MAIL STOP PATENT APPLICATION*
Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450

TRA 1884581v1

CHECKPOINT CT SCANNER SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to baggage inspection systems. More particularly, it relates to a computed tomography (CT) baggage inspection system for detecting security threats.

2. Discussion of Related Art

Security checkpoints, such as in airports, screen people and packages for contraband, such as weapons or explosives. Various technologies are used at such checkpoints. Typically, persons pass through metal detection devices. Baggage and packages are passed through projection x-ray systems. In the current conditions of heightened security, passengers can experience long delays in passing through security checkpoints. The process can be slow and tedious. For baggage, an operator must review all images to determine whether they include contraband. The operators must be highly trained to recognized certain types of objects in the x-ray image. Furthermore, the operator must be able to distinguish objects layered within the bags from a single two dimensional x-ray image. Projection x-ray scanners were designed to provide high resolution images for the detection of guns and knives. They do a reasonable job of that task. Despite the high security screening, many forbidden objects are missed. Specifically, projection x-ray scanners are not designed to detect explosives. Therefore, it is difficult for even the most highly trained screener to detect explosives using projection x-ray technology.

Checked baggage is also now scanned at airports. Generally, computed tomography (CT) scanning is used for checked bags. CT scanners created a three dimensional image of the bag which allows better differentiation of objects than for projection x-rays. CT scanners were specifically developed and deployed for the detection of explosives. However, CT scanners are large, cumbersome and slow. They do not provide a high resolution dual energy projection x-ray image used to detect weapons. They cannot be easily used for carry-on baggage or security checkpoints..

SUMMARY OF THE INVENTION

The present invention includes a CT scanner having a small sized for use with baggage screening at security checkpoints. According to one aspect of the invention, the x-ray data is processed to locate and eliminate non-contraband without full CT reconstruction of the entire bag. Objects of insufficient size, density, or mass are eliminated as potential threats. According to another aspect of the invention, CT reconstruction of objects is used to determine objects of specific sizes and shapes as potential threats. According to another aspect of the invention, the data is processed to locate weapons or explosives without operator review. According to another aspect of the invention, multiple scanners are connected in a network and reconstructed images from multiple scanners are presented to a single operator for review.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a representative image from a projection x-ray system.

Fig. 2 is an image representing data for contraband detection analysis according to an embodiment of the present invention.

Fig. 3 is an image representing a partial reconstructed image according to an embodiment of the present invention.

Fig. 4 is a reconstructed image of a bag according to an embodiment of the present invention.

Fig. 5 is a view of a CT checkpoint scanning system according to an embodiment of the present invention.

DETAILED DESCRIPTION

Fig. 1 illustrates an image of a bag from a projection x-ray system such as the systems used at security checkpoints in airports. The objects in the bag overlap each other in the image. A highly trained operator must review each image to determine whether the bag includes contraband, such as weapons, explosives, or other excluded items. If the objects cannot be clearly viewed, the bag must be hand searched.

In the present invention, small scale CT scanners are used at security checkpoints instead of projection x-ray scanners. Such a small scale CT scanner is disclosed in U.S. Provisional Patent Application Serial No. 60/415,391, entitled "Baggage Inspection System", filed October 2, 2002 and U.S. Patent Application Serial No. 10/677,967, entitled "Folded Array CT Baggage Scanner", filed on October 2, 2003, both of which are incorporated herein by reference in their entirety. Fig. 5 illustrates two parallel systems incorporating the small scale CT scanners according to an embodiment of the present invention.

In order to achieve the compact size without sacrificing the tunnel size or resolution, the small scale CT scanner uses a Folded Array CT. The Folded Array CT has an X-ray source with a fan beam >100°, compared to typical CT using a 60° to 70°

fan beam. This allows the X-ray source to be placed much closer to the inspection tunnel. The Folded Array CT further includes a multi-radial detector concept which breaks the detector array into multiple components placed as close as possible to the inspection tunnel. While optically equivalent to standard CT images, the Folded Array CT system can be made substantially smaller, since all of the imaging components are positioned much closer to the inspection tunnel.

To collect dual energy data, the system incorporates dual energy "stacked" detectors, allowing measurement of both density and effective atomic number for each CT scan. This technology is common in conventional x-ray machines currently at checkpoints. The stacked array contains both high and low energy detectors. The x-ray source maintains a constant flux, avoiding the need to switch energies during the scan. Since there are two detectors the dual energy information is available every time data is collected.

The angular pitch across all detectors is maintained at $1/8^{th}$ of a degree. This allows use of standard equi-angular reconstruction algorithms. The detector pitch remains constant at each of the discrete radii. The detector length (in the bag motion z direction) is also constant at each discrete radius, and is tailored to maintain similar flux intensity for all detectors. The data acquisition system utilizes a 16 bit A/D converter with variable gains, to allow for the simultaneous readouts of both the high and the low signals.

The present invention further includes system for processing data from CT scanner to check from contraband without complete reconstruction of the bag contents.

Such a system is disclosed in U.S. Provisional Patent Application Serial No. 60/442,246, entitled "Method and Apparatus for CT Scanning of Baggage," filed January 23, 2003, and U.S. Patent Application entitled System and Method for CT Baggage Inspection, filed January 23, 2004, both of which are incorporated herein by reference in their entirety.

As set forth in these patent applications, the data are acquired using an approach called the Tomographic and Transmission Analysis Lineogram (ToTAL) Scan. The dual energy data is collected by sampling the detector array at a constant rate of 1440 lines per second, with the gantry rotating at full speed (60 or 90 RPM) and the bag is moving through the system at a constant uniform speed (5 or 10cm/s). This technique allows collection of extremely high-resolution data of the entire bag for analysis. The technique is somewhat analogous to an unreconstructed spiral CT, without the added expense of multiple detector arrays, or the computational requirement of reconstructing every single voxel in the tunnel. The technique makes use of the massive amount of raw data available (up to 288 lines per cm) in its native format rather than performing all detection analysis using the less detailed condensed image after CT reconstruction.

Fig. 2 illustrates sinusoidal data from a CT scanner used in the TotalScan technique. Each sinusoidal line in Fig. 2 represents an object in the baggage. The objects are differentiated by mass, density and atomic number. The objects are then analyzed to eliminate items which lack characteristics as possible contraband. The system can further to acquire a "SnapScan" image, illustrated in Fig. 3. This is a CT image reconstructed from the TotalScan data. SnapScan corrects for motion distortion by "focusing" in on objects of interest and reconstructing only small portions of the entire bag. SnapScan can

be calculated in real time while the bag is moving through the gantry. SnapScan provides density, mass, and atomic number information without having to stop the bag and acquire a full CT slice.

Furthermore, the data can be analyzed to create high resolution CT slices as with conventional CT scanners. Fig. 4 illustrates such an image. Objects may be located within the CT slices or reconstructed as three dimensional objects for review by the system or an operator.

The system also has the capability of acquiring a high resolution dual energy x-ray images of an object by stopping (parking)` the gantry and moving the object rapidly through the x-ray beam.

Many objects at a checkpoint can be automatically eliminate as a potential threat. Objects such as coats, clothing, shoes, coins, and change trays,lack the characteristics for threats, based on x-ray attenuation and size data from a projection x-ray data. This information can be incorporated into the automatic decision process through an x-ray pre-screener attached to the small footprint CT scanner or by parking the gantry. Further items can be eliminated as a weapon by adding in the densityand "Z" information, available from the TotalScan data. TotalScan analyzes an object and determines if there is sufficient mass (and other characteristics) to be a threat, such as an explosive or weapon, including any weapons on the TSA prohibited items list. If an object lacks sufficient mass, density or other characteristic, no further review or analysis is required, including reconstruction of an image or presentation of the image to an operator for review.

If an object is determined to have not enough mass, x-ray attenuation, and/or size to be possible threats or weapons, reconstruction of the bag is not required. It can be passed without further analysis or operator review. It is possible that up to 40% or more of the objects inspected at the checkpoint could be automatically cleared by the system in this manner. Eliminating the need to review images provides labor savings and throughput increases at the checkpoint.

This is an innovative process in that an Explosive Detection Scanner and specifically CT scanners, dual energy and/or multi-view x-ray scanners use sophisticated algorithms to compare objects to threat material scanned in the lab. If there is a sufficient match to the hundred of characteristics of a threat, the system automatically alarms. The object and/or the alarm images are sent to an operator for resolution . The described embodiment approaches "detection" of weapons from the opposite perspective. Using x-ray and/or CT technology objects are "eliminated" as opposed to being "detected". Objects are eliminated based not on hundreds of characteristics but on only one or two characteristics (x-ray attenuation and size for example). These characteristics work uniquely well on carry-on objects as apposed to checked baggage because most (if not all) checked baggage would not be small or light enough to be eliminated. Because of new security regulations, passengers are divesting of far more objects to be placed in the x-ray scanners than previously. Many of these objects (i.e. shoes, belts, coins, cell phones, coats, wallets) can be eliminated by this method.

Furthermore, the method of elimination can be fused with traditional detection methods. Detection of explosives can be accomplished using traditional methods of analyzing hundreds of characteristics using TotalScan, SnapScan, and CT

reconstructions. Weapons such as guns and Knives can be detected using similar techniques in TotalScan, SnapScan, and CT reconstructions. These algorithms include but are not limited too another embodiment called "barrel detection". In this method hundreds of barrel of guns are scanned into a database and the diameter at of these barrels becomes a key search and detection characteristic. Barrel detection is important because a gun can be taken apart and even separated into different bags to avoid detection. The one characteristic that every gun requires and can not be broken down is a barrel. Images and data from a rotating x-ray technology such as CT, is uniquely suited for barrel detection. CT scanners can see the hole or void produced by a gun barrel. Techniques such as TotalScan, SnapScan, and CT reconstructions can be used to detect the void. Other characteristics such as shape, mass, attenuation, and density are other search and detection characteristics that will be used in conjunction with barrel detection.

The system can use SnapScan to reduce the amount of reconstruction or review required. Potential threats can be reconstructed using the SnapScan technique, without the need to reconstruct the contents of an entire bag. The reconstructed object may be further analyzed by the system to determine whether it constitutes a threat. Objects lacking necessary size, density or shape to be an threat or weapon can be further eliminated without operator review. An operator need only review images for potential threats or weapons. The system may provide images of only the objects of interest, or may highlight portions of a bag which are of interest. Thus, the operator is not overloaded by many objects within a bag and can concentrate on the potential threats.

Multiplexing systems will provide additional cost, space, and labor savings. As illustrated in Fig. 5, the small scale CT scanners can be placed close together, back-to-back in clusters of two, for example, at the checkpoint. The operator does not have to stand next to the machine. The data from multiple scanners is provided to a single control room. The multiplexed environment is further enhanced by the weapon's elimination embodiment. Today, screeners spend valuable time and their attention is strained by having to inspect objects that could not possibility be threats. Because screeners stand next to a scanner and are not multiplexed even if weapons elimination was used it would provide no operational benefit. The object may not appear on screen but it consumes a space on the belt of the x-ray machine at a constant speed. In the small CT scanner described above has the ability to increase the velocity of its conveyor belt. So if an object is eliminated the belt in the CT scanner can be accelerated to quickly get the object out of the system. This methodology brings the most benefit in conjunction with an x-ray pre-scanner. In this case, objects are eliminated in the pre-scanner and are rapidly ejected out of the CT engine, improving the overall operation of the system.

Having described at least one embodiment of the invention, modifications, adaptations and improvements will be readily apparent to those of ordinary skill in the art. Such modification, changes and adaptations are considered part of the invention.

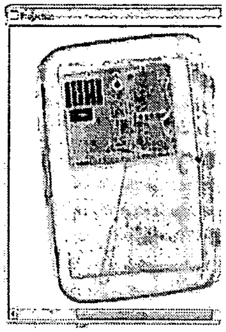


Fig. 1

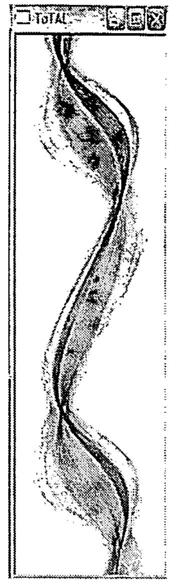


Fig. 2

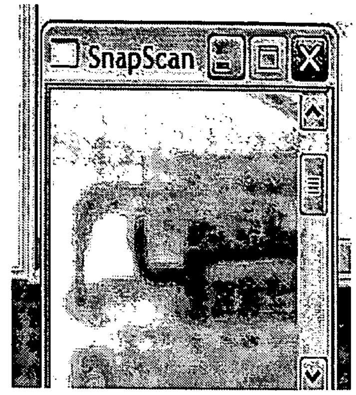
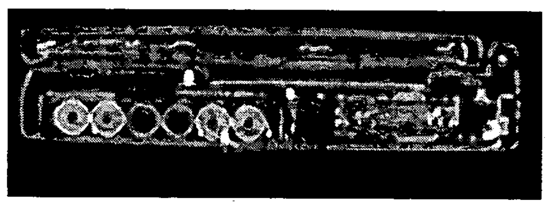


Fig. 3

Fig. 4



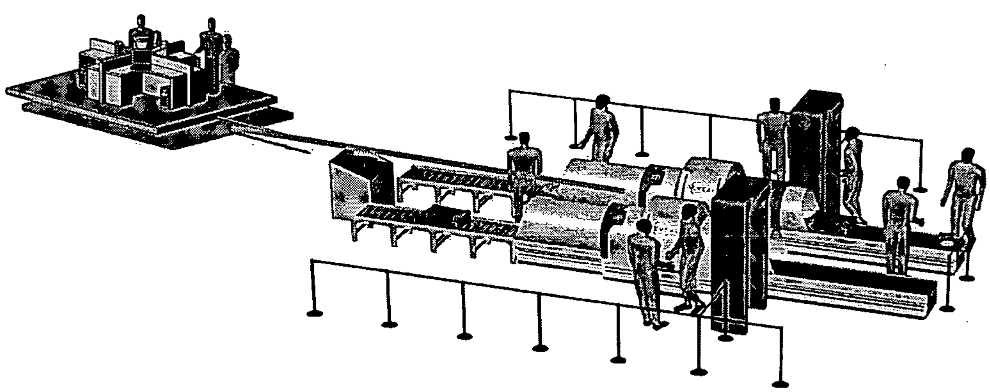


Fig. 5